Senior Thesis

Metamorphic Conditions at an Amphibolite-Granulite Transition Zone in Rogaland/Vest Agder, SW Norway

by

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ABSTRACT

The geology of Southwest Norway is dominated by amphibolite-granulite facies gneisses along with granitic migmatites and other intrusive bodies. Previous work (see references) indicates that four distinct metamorphic events took place in this region. The complex metamorphic history began with two high-grade events at 1.45 Ga (M1) and 1.0 Ga (M2). These two events were followed by regional cooling and formation of retrograde metamorphism (M3). This retrograde metamorphism and partial re-equilibration of certain mineral phases have created a challenge when trying to estimate pressures and temperatures in the area. Pressure and temperature for the M2 event has been estimated to 750°C and 3.5-4.0 kb (Bakker, 1993) and to 750°C and 3.5-4.0 kb (Miller et. al. 1992) for the rocks near the transition zone.

Five thin sections representing the transition zone were selected for this study. A Cameca SX-50 Electron Microprobe was used to analyze the samples for chemical composition. Results from calculations using the Holland-Blundy amphibole-plagioclase thermometers indicate temperatures ranging between 750 °C and 840 °C at pressures 3.5-5.0 kb.

INTRODUCTION

This study focuses on quantitative petrologic investigation of amphibolite-granulite metamorphism, involving the determination of temperature across a metamorphic transition zone in the Rogaland/Vest Agder region in Southwestern Norway. This area is a classic example of an amphibolite-granulite facies transition and is well suited for study because of good exposure and accessibility, and because the general field relations have been well studied (Edwards, 1994). Granulites are a suite of high-grade metamorphic rocks that are formed at temperatures ranging from 700°C to 1000°C and pressures of 4-12 kb, depending on the terrane (Edwards, 1994). The onset of granulite facies metamorphism is usually marked by the appearance of hypersthene (Cramer, 1989). Granulites are a major component in the middle to lower crust. It is therefore important to study granulite terranes in order to understand the origin and evolution of the crust (Edwards, 1994). Many details about the formation of granulites are still unresolved, but research during the last ten years indicates that granulites can form through tectonic processes, such as crustal thickening, or through the addition of heat via magma or fluid advection (Bohlen, 1991; Newton, 1990; Thompson, 1990).

Samples with changes in mineral assemblages suitable for temperature calculations were collected in the Gydal Valley in the summer of 1987, by Barton et. al. For this study, five thin sections were selected for quantitative microprobe analysis, based on their representation of the amphibole-granulite facies transition zone. Thin section 2907872B represents the lower grade metamorphic zone, thin sections 2907875B&C were collected in the transition zone, and samples 2907885B&C represents the higher grade metamorphism. The samples were analyzed for amphiboles, biotites, and plagioclase mineral assemblages. Temperature calculations were made using the Holland-Blundy amphibole-plagioclase thermometer which is based on the equilibrium relationships between amphibole and plagioclase mineral assemblages (Holland-Blundy, 1994).

ROGALAND/VEST AGDER, SOUTHWESTERN NORWAY

REGIONAL GEOLOGY

The Baltic Shield grew concentrically from an Archean crustal nucleus which was caused by several major crust forming events between 3.5 and 1.5 Ga (Gaal and Gorbatschev, 1987). The Baltic Shield, covering most of the Scandinavian Peninsula, is divided into three crustal domains based on age, metamorphism, and tectonic style (Gaál and Gorbatschev, 1987; Lindh, 1987). These domains formed and were deformed during distinct orogenic episodes that reflect alternating accretional and rifting/dispersional regimes (Gaal and Gorbatschev, 1987; Gorbatschev 1990). The Rogaland/Vest Agder granulite terrane of SW Norway is located within the Southwest Scandinavian Domain and consists of rocks with an approximate age of 1.5 Ga. The Rogaland terrane is dominated by a Precambrian high-grade metamorphic complex consisting of amphibolite-granulite facies migmatites, granitic gneisses, and augen gneisses (Figure 1). The complex history recorded by these units reflects a series of tectonic events, dominated by reworking of the crust.

The metamorphic history of the Rogaland/Vest Agder terrane is complicated, but can be subdivided into four episodes (denoted M1-M4). The initial episode (M1) occurred at approximately 1.2 Ga and represents upper amphibolite facies metamorphism (Jansen et. al., 1985). The M2 episode occurred at circa 1.05 Ga. The grade of metamorphism ranges from upper amphibolite facies in the east to granulite facies in the west. For the M2 metamorphic event Bakker et. al. (1993) has calculated temperatures of 750°C and pressures of 3.5-4.0 kb for the rocks near the transition zone, while Miller et. al. (1992) has calculated temperatures of 780°C-820°C and pressures of 3.5-5.0 kb for the same rocks. Both sets of calculations indicate higher temperatures close to the intrusive complex. Events M1 and M2 reflect high-grade metamorphism associated with intrusion of anorthisitic-leuconoritic-noritic-monzonoritic magmas (Edwards, 1994). The M3 event reflects retrograde metamorphism during slow cooling and uplift between 0.95 and 0.98 Ga (Verschure, 1985). Mineral assemblages have been re-equilibriated at temperatures of 650 °C - 750 °C and pressures of 3.5-5.0 kb. The M4 episode at 400 Ma was a widespread, weak, low-grade event associated with overthrusting within the Caledonian orogeny and produced prehnite-pumpellyite to lower greenschist facies assemblages (Sauter et. al., 1983; Jansen et. al., 1985, Barton and Van Bergen 1984).

P-T-t diagrams for the Rogaland/Vest Agder are consistent with a clockwise direction (Figure 3) which typically results from continental collision and crustal thickening (Edwards, 1994). The P-T-t path is discussed in Edwards (1994) from which the following is taken.

An inferred Proterozoic crustal thickness of 50-60 km (Demaiffe and Michot, 1985), together with recumbent folding during early high-grade metamorphism (Hermans et. al.; 1975, Huijsmans et. al., 1981) is consistent with crustal thickening resulting from obduction with plate collision (Demaiffe and Michot, 1985), or lithospheric doubling (Vlaar, 1985). The exact P-T trajectory of the retrograde path is uncertain, but cooling was nearly isobaric (Jansen et. al., 1985). This suggest that extension followed the thickening and was probably important for the emplacement of the Hunnedalen dike system about 900 Ma (Barton et. al., 1991).

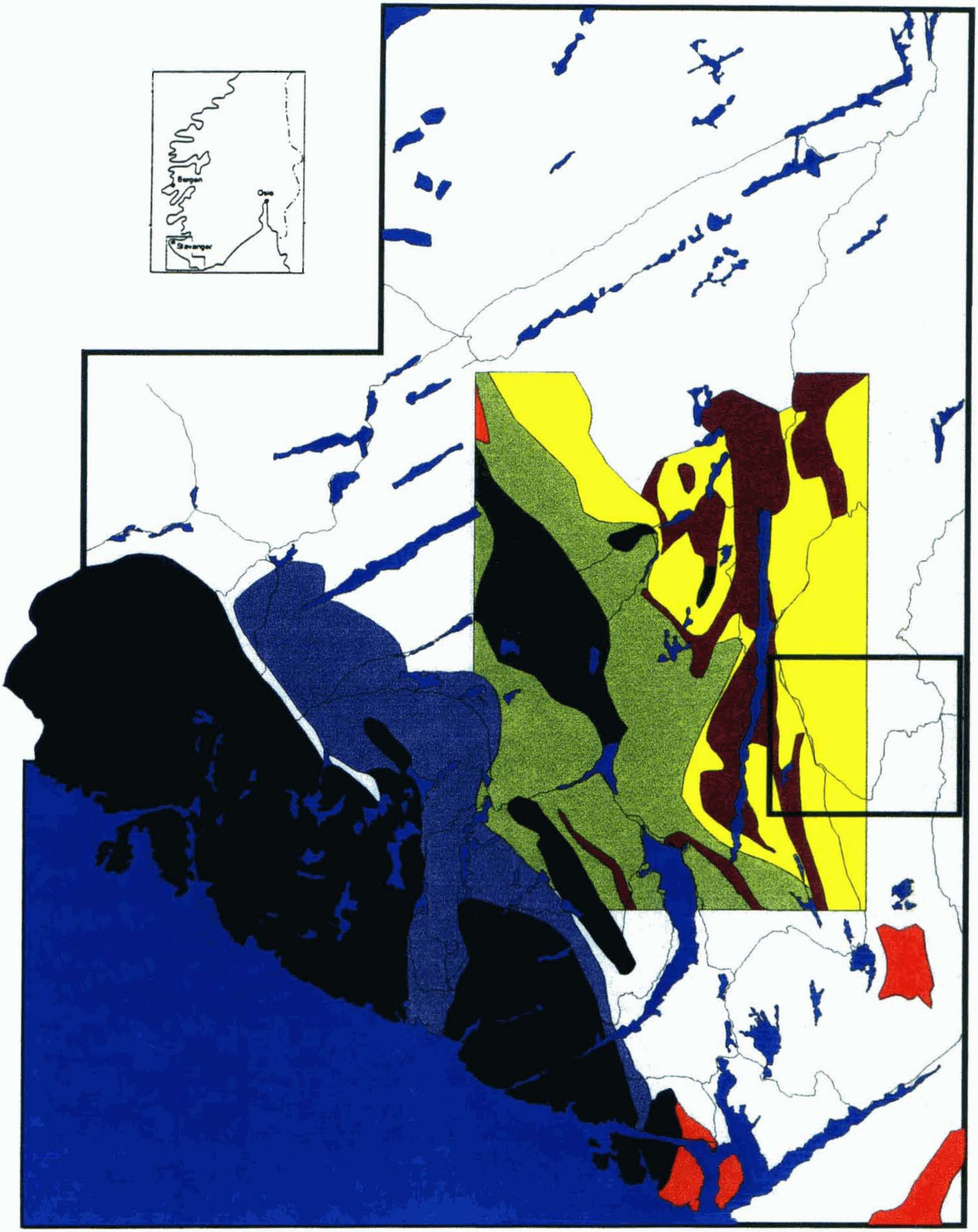

Figure 1. Geologic map of the Rogaland/Vest Agder region of Southwest Norway showing the distribution of the major intrusive bodies (Miller, 1996).

Figure 1a. Legend for Figure 1.

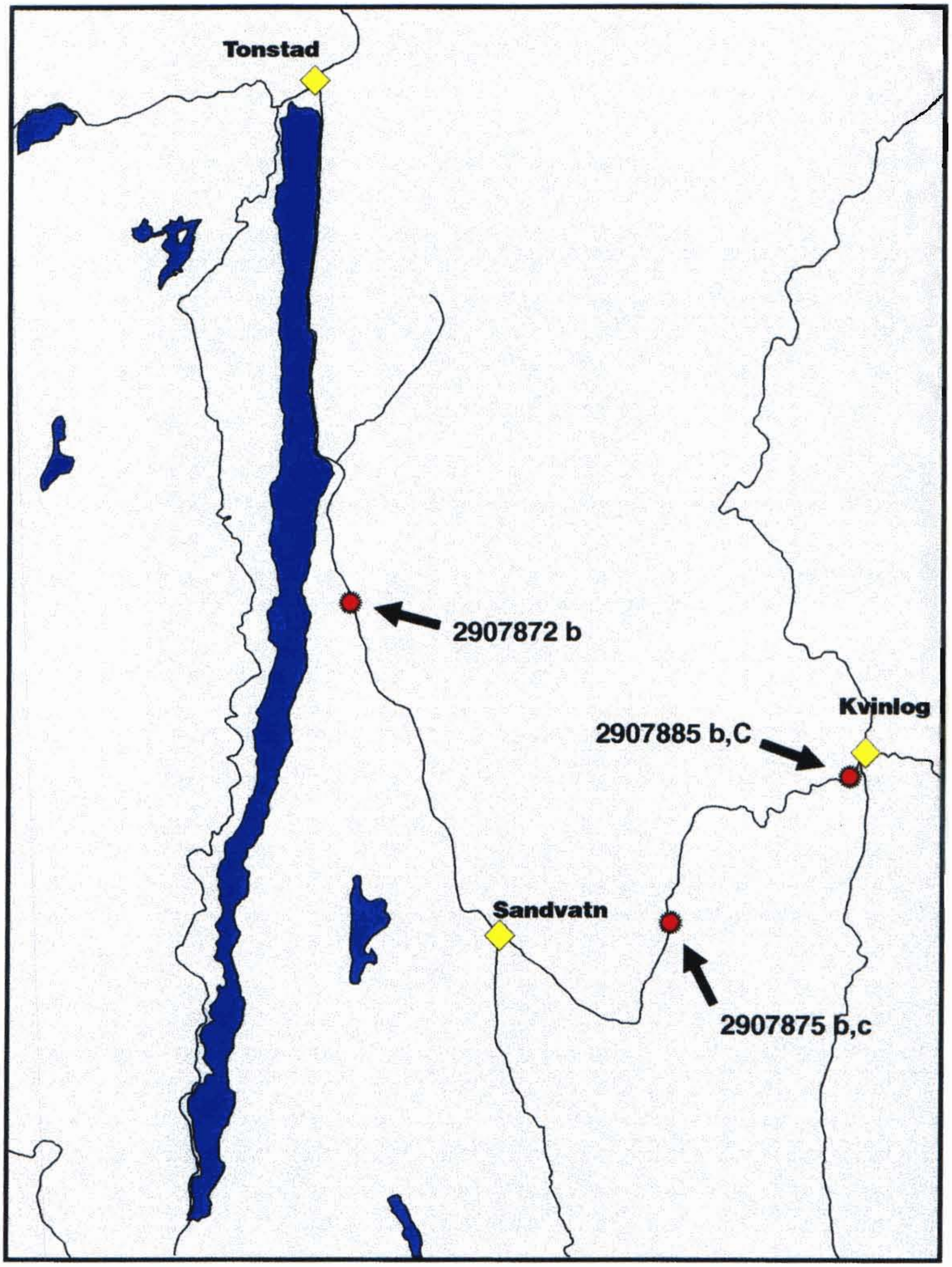

Figure 2. This map of the field area indicates the locations of the samples analyzed in this study.

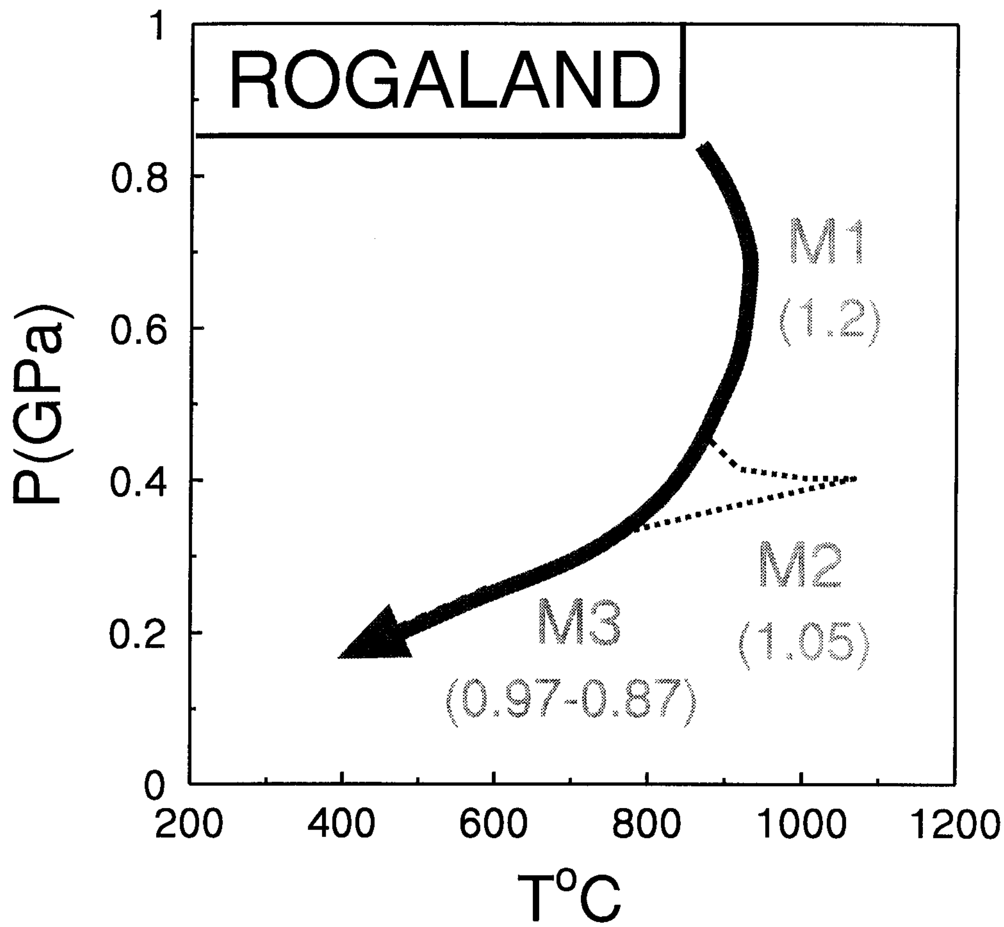

Figure 3. Generalized P-T-t path for the Rogaland region based on quantitative estimates from Miller et. al. (1992).

ANALYTICAL PROCEDURES

Minerals in selected samples were analyzed using a Cameca SX-50 microprobe. The samples were analyzed for amphiboles, biotites, and feldspars. Representative analyses can be found in appendices A, B, and C. Mineral compositions for amphiboles and biotites were determined using a beam size of one micron, an accelerating voltage of 15 kV, and a beam current of 15 nA. Feldspars were analyzed using a beam-size of 5 microns to avoid beam-induced Na migration. Count times varied between 15 and 30 seconds, depending on the concentration of the element being analyzed.

Minerals were selected for their apparent lack of alteration and textural equilibrium. Only cores of isolated grains were selected for computational purposes to avoid effects from possible alteration at the edges. Descriptions of the selected thin section used for this study can be found in Appendix D.

DATA ANALYSIS

The feldspar analyses were plotted in a triangular diagram based on Na (albite), K (orthoclase), and Ca (anorthite) content (Figure 4). This diagram does not indicate a distinct variation in feldspar composition across the transition zone.. It appears that samples 2907875B & C have the highest content of anorthite, approximately 40 %, while samples 2907885B & C and 2907872B consist mostly of albite, approximately 70 -80 %. Not more than 5% of orthoclase is present in any of the samples.

The chemical composition of the amphiboles were plotted in figure 5 based on the Al^{iv} content and the combined amount of Na and K. A slight variation in the composition can be seen. The amount of Al^{iv} increases toward the higher-grade metamorphism, but the Na + K content remains more or less constant for all five samples.

The fluorine content of the amphiboles are listed in table 1. Two distinct populations can be seen. The thin section at lower-grade metamorphism, 2907872B, and the thin sections at higher-grade metamorphism, 2907885B & C, contain more fluorine than thin sections 2907875B & C, hence forming a bimodal set of data.

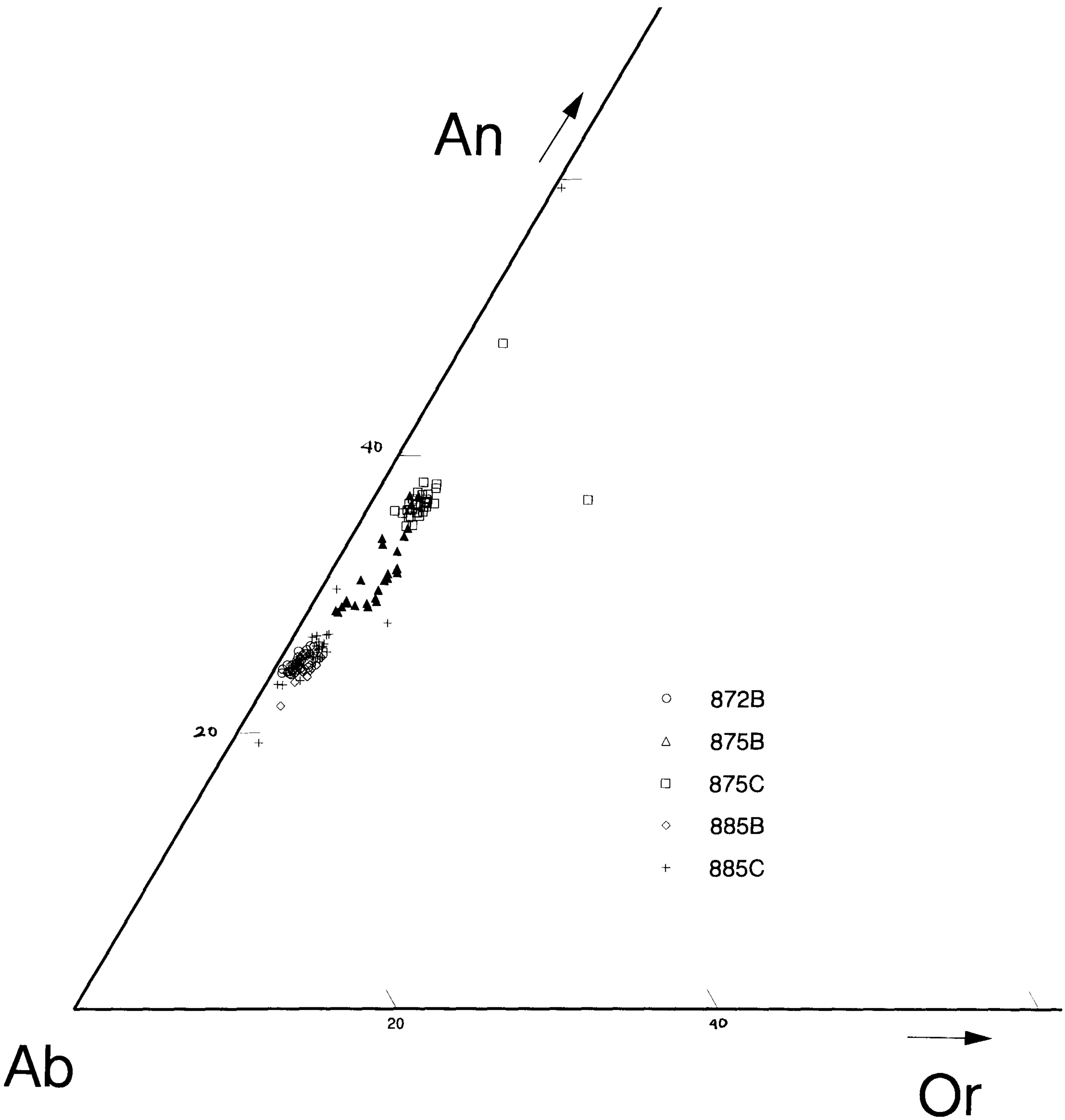

Figure 4. Triangular diagram of feldspar composition based on the relative calcium, potassium, and sodium content.

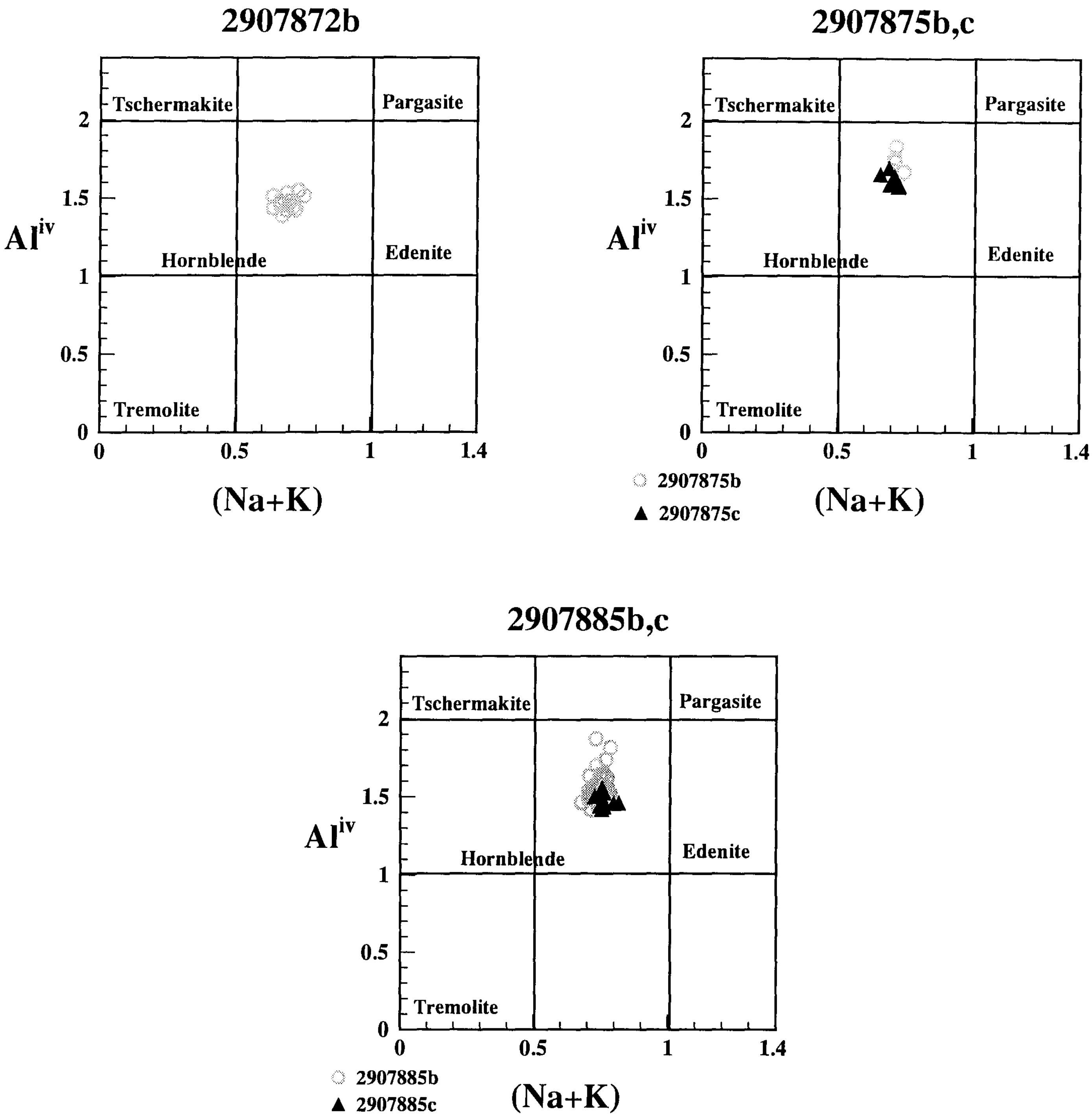

Figure 5. Diagram showing the Al^{iv} content compared to the combined amount of sodium and potassium.

Table 1. Flourine Content in Each Thin Section

2907872B	2907875B	2907875C	2907885B	2907885C
0.006	0.004	0.009	0.033	0.028
0.021	0.023	0.013	0.033	0.028
0.027	0.029	0.016	0.036	0.039
0.036	0.037	0.019	0.039	0.049
0.036		0.026	0.042	0.056
0.037		0.031	0.044	0.058
0.037		0.039	0.045	0.067
0.039			0.048	0.068
0.039			0.048	
0.040			0.048	
0.045			0.049	
0.060			0.052	
			0.055	
			0.056	
			0.059	
			0.059	
			0.060	
			0.060	
			0.064	
			0.065	

GEOTHERMOMETRY

The Holland-Blundy amphibole-plagioclase thermometer was used to calculate temperatures across the transition zone. The thermometer calculations are based on the equilibrium of amphibole and plagioclase mineral assemblages and takes into account non-ideal mixing in both amphiboles and plagioclase as illustrated in these two reactions:

$$\underset{\text{edenite}}{NaCa_2Mg_5(AlSi_3)Si_4O_{22}(OH)_2} + \underset{\text{quartz}}{4\ SiO_2} \text{ -----> } \underset{\text{tremolite}}{Ca_2(Mg_{0.9}Fe^{2+}{}_{0.1})_5Si_8O_{22}(OH)_2} + \underset{\text{albite}}{NaAlSi_3O_8} \quad (1)$$

$$\underset{\text{edenite}}{NaCa_2Mg_5(AlSi_3)Si_4O_{22}(OH)_2} + \underset{\text{albite}}{NaAlSi_3O_8} \text{ -----> } \underset{\text{richterite}}{Na(CaNa)Mg_5Si_8O_{22}(OH)_2} + \underset{\text{anorthite}}{CaAl_2Si_2O_8} \quad (2)$$

Selected analyses of amphiboles and feldspars (Tables 2 and 3) were used in the Holland-Blundy amphibole-plagioclase thermometer to calculate the temperature for four different pressures. (Table 4). The pressures were chosen based on estimated values by Miller (1992). Each analysis has been assigned a number and the temperatures were calculated from different combinations of the analyses, as indicated in Table 3. The temperatures range from 750 °C to as high as 840 °C. The average temperature across the transition zone is 787 °C.

Table 2. Representative Table of Amphibole Analysis.
This data was used in the amphibole-plagioclase thermometer to calculate the temperature.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Label	**7872B**	**7872B**	**7875B**	**7875B**	**7875C**	**7875C**	**7885B**	**7885B**	**7885C**	**7885C**
SiO_2	41.704	43.242	39.332	40.303	41.139	40.923	43.349	42.307	42.738	43.097
TiO_2	1.206	1.176	1.443	1.416	1.985	2.361	1.817	2.030	1.864	1.940
Al_2O_3	9.500	8.994	10.679	10.919	10.341	10.099	9.290	9.368	9.175	8.858
Cr_2O_3	0.142	0.177	0.118	0.133	0.069	0.000	0.000	0.000	0.089	0.115
FeO	18.950	16.974	18.568	18.644	20.316	20.598	15.763	15.983	15.613	15.970
MnO	0.515	0.531	0.487	0.577	0.258	0.247	0.464	0.395	0.398	0.403
MgO	9.789	11.855	9.686	9.434	8.482	8.293	11.950	11.824	12.054	11.747
CaO	11.556	11.514	11.175	10.929	10.937	10.988	11.312	11.221	10.879	11.181
Na_2O	1.592	1.490	1.295	1.414	1.365	1.386	1.666	1.697	1.836	1.676
K_2O	1.367	1.262	1.527	1.554	1.578	1.497	1.400	1.418	1.388	1.320
F	1.003	1.052	1.003	0.624	1.054	0.352	1.731	0.743	1.800	1.046
Cl	0.325	0.262	0.045	0.034			0.096	0.076	0.101	0.082
Total	**97.649**	**98.575**	**95.360**	**95.982**	**97.622**	**96.843**	**98.886**	**97.090**	**97.933**	**97.436**
Mole Prop.	9.347	9.136	9.568	9.439	9.368	9.394	9.100	9.205	9.196	9.179
Si	6.487	6.575	6.263	6.331	6.414	6.398	6.565	6.482	6.541	6.584
Ti	0.141	0.134	0.173	0.167	0.233	0.278	0.207	0.234	0.214	0.223
Al	1.742	1.612	2.004	2.022	1.900	1.861	1.658	1.692	1.655	1.595
AlIV	1.513	1.425	1.737	1.669	1.586	1.602	1.435	1.518	1.459	1.416
AlVI	0.229	0.187	0.268	0.353	0.314	0.259	0.223	0.173	0.196	0.179
Fe	2.465	2.158	2.473	2.449	2.649	2.693	1.997	2.048	1.998	2.040
Mn	0.068	0.068	0.066	0.077	0.034	0.033	0.059	0.051	0.052	0.052
Mg	2.270	2.687	2.299	2.209	1.971	1.933	2.697	2.700	2.750	2.675
Ca	1.925	1.875	1.906	1.839	1.826	1.840	1.835	1.841	1.783	1.829
Na	0.480	0.439	0.400	0.431	0.413	0.420	0.489	0.504	0.545	0.496
K	0.271	0.245	0.310	0.311	0.314	0.299	0.270	0.277	0.271	0.257
F	0.347	0.356	0.356	0.218	0.366	0.123	0.583	0.253	0.613	0.356
Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3. Representative Table of Feldspar Analyses.
This data was used in the amphibole-plagioclase thermometer to calculate the temperature.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Label	**7872B**	**7872B**	**7875B**	**7875B**	**7875B**	**7875C**	**7875C**	**7875C**	**7885B**	**7885B**	**7885C**	**7885C**	**7885C**
SiO_2	61.057	61.594	59.529	59.959	58.740	58.353	58.047	59.411	60.980	61.099	60.888	61.168	61.416
Al_2O_3	24.797	24.512	25.404	24.845	25.782	26.099	26.292	26.116	24.455	24.191	24.316	24.427	24.100
Sr_2O_5	0.000	0.080	0.000	0.000	0.000	0.000	0.000	0.068	0.000	0.000	0.057	0.000	0.012
CaO	5.162	5.013	6.408	5.948	7.119	7.459	7.813	7.218	5.104	5.265	5.430	5.197	4.892
FeO	0.107	0.225	0.152	0.099	0.154	0.197	0.051	0.093	0.078	0.078	0.148	0.082	0.013
BaO	0.000	0.087	0.119	0.144	0.073	0.075	0.037	0.063	0.000	0.048	0.173	0.000	0.186
Na_2O	8.546	8.449	7.404	7.931	7.022	6.931	6.734	7.094	8.361	8.244	8.109	8.357	8.727
K_2O	0.116	0.090	0.650	0.294	0.560	0.622	0.438	0.534	0.400	0.436	0.373	0.229	0.133
Total	**99.784**	**100.051**	**99.667**	**99.220**	**99.449**	**99.735**	**99.413**	**100.598**	**99.379**	**99.362**	**99.494**	**99.460**	**99.478**
Prop.	2.995	3.004	2.973	2.967	2.963	2.965	2.960	2.999	2.981	2.979	2.979	2.986	2.985
# Anions	5.007	4.995	5.003	5.005	4.999	5.008	4.998	4.999	5.006	5.001	5.000	4.998	5.008
An	24.858	24.562	31.136	28.803	34.740	35.961	38.072	34.885	24.645	25.432	26.425	25.235	23.470
Or	0.663	0.527	3.763	1.695	3.254	3.568	2.544	3.071	2.299	2.508	2.164	1.323	0.757
Al	74.479	74.911	65.102	69.503	62.005	60.471	59.384	62.044	73.056	72.061	71.411	73.442	75.773

Table 4. Temperatures calculated after the Holland-Blundy Model.

Thinsection	Analyses Combinations from Tables 1 & 2	P = 3.0kb	P = 3.5kb	P = 4.0kb	P = 4.5kb
			Temperatures (°C)		
2907872B	I-1	752	753	755	756
2907872B	I-2	751	752	753	754
2907872B	II-2	798	796	795	794
2907875B	III-4	809	811	812	813
2907875B	III-3	821	823	824	825
2907875B	III-5	833	796	836	837
2907875C	VI-7	753	757	761	765
2907875C	VI-6	748	752	756	760
2907885B	VIII-10	816	816	815	815
2907885B	VIII-9	813	812	812	811
2907885C	IX-11	786	787	788	789
2907885C	IX-12	780	781	782	783
2907885C	X-12	773	773	774	774
2907885C	X-13	766	767	767	767

DISCUSSION OF RESULTS

The percent anorthite/albite present in the five thin sections ranges between 20-40% anorthite. This is consistent with previous work by Cramer (1989) who estimated the anorthite content in these samples to range between 28-38%.

The Al^{iv} content increases toward the higher grade metamorphism. This is consistent with previous work (Miller et. al.), indicating that the Al^{iv} content increases with increasing pressure.

The effects of fluorine on the stability of amphiboles is an area that has not been well studied. Work being done by Comerford indicates that an increased amount of fluorine in amphiboles increase their stability at higher temperatures, which can be determined from the analyses in Appendix A.

The results from the Holland-Blundy thermometer calculations indicate that the temperatures range from approximately 750°C to as high as 840°C (table 4). It can also be seen that temperatures increase when approaching the higher-grade metamorphism. This result confirms previous estimated temperatures by Miller (1992).

CONCLUSION

In order to understand the formation of granulites, it is necessary to have well-constrained estimates of the temperature and pressure conditions during metamorphism. Results obtained in this study do seem to confirm previous estimated temperatures for the M2 metamorphic event across the granulite-amphibolite transition zone in Rogaland/Vest Agder, SW Norway. The results are consistent with the general known conditions for granulite metamorphism in this region and with previous quantitative temperature and pressure estimates from nearby granulites such as those estimates found in Edwards (1994) work. The results from this study is also consistent with the clockwise P-T-t path established by Miller (1992).

ACKNOWLEDGMENTS

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APPENDIX A

MICROPROBE ANALYSES FOR AMPHIBOLES

Note: F, Cl are given in moles, not weight percent

Amphibole Analyses for Thin Section 2907872B

	Amp14E	Amp11E	Amp15C	Amp10C	Amp13C	Amp14C	Amp11C
SiO_2	43.099	42.404	42.329	43.953	43.242	42.254	43.232
TiO_2	1.301	0.769	0.923	1.068	1.176	1.049	0.973
Al_2O_3	9.098	9.098	8.924	9.302	8.994	9.166	9.362
Cr_2O_3	0.281	0.101	0.205	0.272	0.177	0.168	0.118
FeO	16.284	17.656	17.615	16.822	16.974	17.465	17.688
MnO	0.501	0.474	0.515	0.516	0.531	0.591	0.462
MgO	11.810	11.620	11.625	11.649	11.855	11.736	11.557
CaO	11.854	11.854	11.571	11.673	11.514	11.774	11.777
Na_2O	1.347	1.399	1.506	1.469	1.490	1.294	1.418
K_2O	1.236	1.253	1.255	1.261	1.262	1.282	1.287
F	0.006	0.036	0.045	0.037	0.039	0.060	0.039
Cl	0.006	0.007	0.006	0.006	0.006	0.006	0.006
Total	96.823	96.670	96.518	98.029	97.307	96.845	97.918
Si	6.564	6.523	6.525	6.612	6.575	6.489	6.549
Ti	0.149	0.089	0.107	0.121	0.134	0.121	0.111
AlIV	1.436	1.477	1.475	1.388	1.425	1.511	1.451
AlVI	0.198	0.173	0.146	0.262	0.187	0.148	0.220
Fe	2.074	2.272	2.271	2.117	2.158	2.243	2.241
Mn	0.065	0.062	0.067	0.066	0.068	0.077	0.059
Mg	2.681	2.664	2.671	2.612	2.687	2.686	2.609
Ca	1.934	1.953	1.910	1.881	1.875	1.937	1.911
Na	0.398	0.417	0.450	0.429	0.439	0.385	0.416
K	0.240	0.246	0.247	0.242	0.245	0.251	0.249

Amphibole Analyses for Thin Section 2907872B

	Amp12E	Amp13E	Amp12C	Amp1C	Amp2E
SiO_2	41.751	43.311	43.247	41.704	41.984
TiO_2	0.861	1.006	1.143	1.206	1.039
Al_2O_3	9.657	9.075	9.009	9.500	9.769
Cr_2O_3	0.092	0.232	0.123	0.142	0.222
FeO	16.754	17.352	16.835	18.950	18.958
MnO	0.469	0.527	0.550	0.515	0.475
MgO	11.547	11.878	11.679	9.789	10.316
CaO	11.778	11.603	11.841	11.556	11.714
Na_2O	1.441	1.569	1.583	1.592	1.514
K_2O	1.288	1.289	1.308	1.367	1.424
F	0.036	0.021	0.040	0.037	0.027
Cl	0.006	0.006	0.005	0.007	0.008
Total	95.680	97.963	97.379	96.366	97.450
Si	6.470	6.558	6.575	6.487	6.454
Ti	0.100	0.115	0.131	0.141	0.120
AlIV	1.530	1.442	1.425	1.513	1.546
AlVI	0.233	0.178	0.189	0.229	0.224
Fe	2.171	2.197	2.140	2.465	2.437
Mn	0.062	0.068	0.071	0.068	0.062
Mg	2.667	2.681	2.647	2.270	2.364
Ca	1.955	1.882	1.928	1.925	1.929
Na	0.433	0.461	0.466	0.480	0.451
K	0.255	0.249	0.254	0.271	0.279

Amphibole Analyses for Thin Section 2907875B

	Amp 3C	Amp 2E	Amp 2C	Amp 4E
SiO_2	38.328	38.613	39.332	40.303
TiO_2	1.491	1.326	1.443	1.416
Al_2O_3	10.957	10.492	10.679	10.919
Cr_2O_3	0.178	0.196	0.118	0.133
FeO	18.736	18.468	18.568	18.644
MnO	0.524	0.462	0.487	0.577
MgO	9.709	9.650	9.686	9.434
CaO	10.846	11.062	11.175	10.929
Na_2O	1.355	1.277	1.295	1.414
K_2O	1.418	1.493	1.527	1.554
F	0.029	0.004	0.037	0.023
Cl	0.001	0.001	0.001	0.001
Total	**93.575**	**93.042**	**94.349**	**95.347**
Si	6.169	6.243	6.263	6.331
Ti	0.181	0.161	0.173	0.167
AlIV	1.831	1.757	1.737	1.669
AlVI	0.247	0.242	0.268	0.353
Fe	2.522	2.497	2.473	2.449
Mn	0.071	0.063	0.066	0.077
Mg	2.329	2.325	2.299	2.209
Ca	1.870	1.916	1.906	1.839
Na	0.423	0.400	0.400	0.431
K	0.291	0.308	0.310	0.311

Amphibole Analyses for Thin Section 2907875C

	Amp 1	Amp 6	Amp 3	Amp 5-1	Amp 4	Amp 5	Amp 2
SiO_2	40.953	40.859	40.579	40.923	40.996	41.139	40.898
TiO_2	1.678	2.009	1.785	2.361	2.044	1.985	1.710
Al_2O_3	10.749	10.316	10.760	10.099	9.865	10.341	10.301
Cr_2O_3	0.000	0.085	0.031	0.000	0.060	0.069	0.000
FeO	21.873	20.312	21.230	20.598	20.845	20.316	20.338
MnO	0.243	0.274	0.214	0.247	0.296	0.258	0.243
MgO	8.686	9.106	8.767	8.293	8.306	8.482	8.547
CaO	10.693	10.950	11.114	10.988	11.097	10.937	11.226
Na_2O	1.235	1.396	1.299	1.386	1.384	1.365	1.233
K_2O	1.443	1.450	1.495	1.497	1.519	1.578	1.589
F	0.031	0.019	0.016	0.013	0.026	0.039	0.009
Cl	0.003	0.003	0.003	0.002	0.003	0.002	0.003
Total	**97.587**	**96.860**	**97.293**	**96.407**	**96.440**	**96.513**	**96.096**
Si	6.345	6.355	6.305	6.398	6.421	6.414	6.409
Ti	0.196	0.235	0.209	0.278	0.241	0.233	0.202
AlIV	1.655	1.645	1.695	1.602	1.579	1.586	1.591
AlVI	0.308	0.246	0.276	0.259	0.243	0.314	0.312
Fe	2.834	2.642	2.759	2.693	2.731	2.649	2.665
Mn	0.032	0.036	0.028	0.033	0.039	0.034	0.032
Mg	2.006	2.111	2.031	1.933	1.939	1.971	1.996
Ca	1.774	1.824	1.850	1.840	1.862	1.826	1.884
Na	0.371	0.421	0.391	0.420	0.420	0.413	0.375
K	0.285	0.288	0.296	0.299	0.304	0.314	0.318

Amphibole Analyses for Thin Section 2907885B

	Amp10C	Amp10E	Amp11C	Amp11C	Amp11E	Amp1E	Amp2C	Amp2C
SiO_2	42.930	43.520	41.969	42.949	43.210	42.472	43.349	43.189
TiO_2	2.089	1.828	1.795	1.905	1.915	1.428	1.817	1.495
Al_2O_3	9.325	9.508	9.366	9.068	9.466	9.028	9.290	9.287
Cr_2O_3	0.101	0.000	0.018	0.042	0.016	0.050	0.048	0.012
FeO	15.346	15.456	15.628	15.985	15.649	16.180	15.763	16.269
MnO	0.444	0.393	0.365	0.377	0.399	0.343	0.464	0.350
MgO	12.387	12.555	12.155	12.460	12.149	12.276	11.950	12.321
CaO	11.804	11.781	11.802	11.799	11.801	11.664	11.312	12.082
Na_2O	1.631	1.628	1.655	1.518	1.504	1.562	1.666	1.591
K_2O	1.406	1.406	1.340	1.341	1.367	1.355	1.400	1.358
F	0.048	0.049	0.048	0.059	0.042	0.044	0.064	0.048
Cl	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Total	**97.511**	**98.126**	**96.144**	**97.505**	**97.521**	**96.405**	**97.126**	**98.003**
Si	6.373	6.443	6.540	6.369	6.361	6.358	6.385	6.572
Ti	0.157	0.207	0.239	0.249	0.173	0.157	0.224	0.225
AlIV	1.627	1.557	1.460	1.631	1.639	1.642	1.615	1.428
AlVI	0.138	0.138	0.205	0.151	0.090	0.050	0.137	0.150
Fe	2.070	2.007	2.030	1.853	2.114	2.020	2.101	2.013
Mn	0.048	0.047	0.049	0.056	0.056	0.048	0.051	0.052
Mg	2.859	2.781	2.613	2.903	2.836	3.007	2.690	2.687
Ca	1.935	1.941	1.915	1.919	1.951	1.975	1.938	1.917
Na	0.491	0.493	0.416	0.440	0.474	0.486	0.473	0.469
K	0.266	0.262	0.261	0.268	0.271	0.276	0.274	0.271

Amphibole Analyses for Thin Section 2907885B

	Amp2E	Amp4C	Amp4E	Amp5E	Amp6C	Amp7C	Amp7E	Amp8C
SiO_2	42.981	42.286	43.020	42.733	43.381	43.007	42.949	42.487
TiO_2	1.874	1.748	2.090	1.538	1.875	1.782	1.673	1.520
Al_2O_3	9.292	9.137	9.294	9.479	9.018	9.417	9.444	9.351
Cr_2O_3	0.028	0.053	0.000	0.045	0.064	0.000	0.037	0.000
FeO	16.035	16.283	15.967	16.126	16.049	15.501	15.471	16.196
MnO	0.360	0.338	0.378	0.430	0.396	0.416	0.400	0.362
MgO	11.925	12.215	11.533	11.941	12.497	12.333	12.217	12.379
CaO	11.459	11.671	11.759	11.587	11.636	11.615	11.776	11.464
Na_2O	1.614	1.512	1.410	1.545	1.628	1.549	1.636	1.561
K_2O	1.350	1.367	1.348	1.437	1.368	1.348	1.342	1.395
F	0.056	0.052	0.033	0.060	0.055	0.045	0.033	0.060
Cl	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.001
Total	**96.976**	**96.665**	**96.834**	**96.939**	**97.970**	**97.013**	**96.980**	**96.775**
Si	6.563	6.506	6.476	6.444	6.512	6.528	6.508	6.506
Ti	0.207	0.176	0.187	0.237	0.191	0.214	0.165	0.169
AlIV	1.437	1.494	1.524	1.556	1.488	1.472	1.492	1.494
AlVI	0.220	0.207	0.130	0.087	0.199	0.192	0.138	0.155
Fe	1.996	2.053	2.023	2.000	1.962	2.037	2.073	2.050
Mn	0.059	0.055	0.046	0.046	0.051	0.046	0.045	0.045
Mg	2.696	2.710	2.814	2.806	2.761	2.700	2.804	2.767
Ca	1.834	1.889	1.943	1.959	1.912	1.864	1.914	1.950
Na	0.489	0.456	0.480	0.465	0.481	0.475	0.464	0.465
K	0.270	0.279	0.253	0.261	0.260	0.262	0.265	0.261

Amphibole Analyses for Thin Section 2907885B

	Amp8C	Amp9C	Amp9C	Amp8E
SiO_2	42.838	42.956	43.197	43.356
TiO_2	1.984	1.957	1.793	1.917
Al_2O_3	9.190	8.748	9.432	9.260
Cr_2O_3	0.073	0.000	0.019	0.077
FeO	15.936	15.730	15.729	15.762
MnO	0.399	0.400	0.374	0.418
MgO	12.218	11.782	12.460	12.323
CaO	11.589	11.699	11.630	11.655
Na_2O	1.584	1.583	1.739	1.658
K_2O	1.389	1.389	1.323	1.359
F	0.065	0.036	0.059	0.039
Cl	0.002	0.002	0.002	0.002
Total	**97.267**	**96.281**	**97.758**	**97.827**
Si	6.521	6.468	6.514	6.452
Ti	0.217	0.201	0.217	0.213
AlIV	1.479	1.532	1.486	1.548
AlVI	0.163	0.115	0.196	0.132
Fe	1.983	2.083	1.973	1.988
Mn	0.053	0.044	0.051	0.052
Mg	2.763	2.785	2.730	2.780
Ca	1.878	1.912	1.906	1.967
Na	0.484	0.449	0.440	0.453
K	0.261	0.267	0.263	0.276

Amphibole Analysis for Thin Section 2907885C

	Amp1	Amp1	Amp2	Amp3	Amp4	Amp5	Amp6	Amp6-1
SiO_2	42.958	42.738	43.097	42.434	42.688	43.046	42.113	43.018
TiO_2	1.668	1.864	1.940	1.745	1.747	1.815	2.020	1.770
Al_2O_3	8.824	9.175	8.858	9.249	8.981	9.128	9.217	9.069
Cr_2O_3	0.042	0.089	0.115	0.000	0.003	0.000	0.039	0.048
FeO	16.160	15.613	15.970	15.624	15.902	15.743	15.662	15.875
MnO	0.453	0.398	0.403	0.425	0.418	0.435	0.425	0.404
MgO	11.945	12.054	11.747	12.044	12.026	11.925	12.299	11.955
CaO	11.388	10.879	11.181	11.665	11.283	11.375	11.517	11.524
Na_2O	1.639	1.836	1.676	1.564	1.653	1.624	1.662	1.789
K_2O	1.413	1.388	1.320	1.332	1.387	1.361	1.329	1.387
F	0.058	0.067	0.039	0.028	0.056	0.068	0.049	0.028
Cl	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Total	**96.549**	**96.101**	**96.348**	**96.112**	**96.145**	**96.522**	**96.334**	**96.869**
Si	6.477	6.567	6.449	6.503	6.561	6.544	6.544	6.541
Ti	0.193	0.192	0.233	0.201	0.208	0.201	0.203	0.214
AlIV	1.523	1.433	1.551	1.497	1.439	1.456	1.456	1.459
AlVI	0.140	0.156	0.113	0.174	0.201	0.167	0.170	0.196
Fe	2.117	2.066	2.006	2.002	2.007	2.039	2.020	1.998
Mn	0.055	0.059	0.055	0.055	0.056	0.054	0.052	0.052
Mg	2.676	2.721	2.807	2.751	2.709	2.748	2.711	2.750
Ca	1.933	1.865	1.889	1.915	1.857	1.853	1.878	1.783
Na	0.482	0.486	0.493	0.465	0.480	0.491	0.528	0.545
K	0.278	0.276	0.260	0.260	0.265	0.271	0.269	0.271

APPENDIX B

MICROPROBE ANALYSES FOR BIOTITES

Biotite Analyses for Thin Section 2907872B

	Bio 4E	Bio 1E	Bio 2C	Bio 14E	Bio 2C	Bio 4C	Bio 15C	Bio 3E	Bio
SiO_2	35.834	33.628	36.944	36.970	36.495	35.310	36.544	36.634	36.593
TiO_2	3.740	3.447	4.268	3.095	3.660	3.674	2.895	3.652	4.107
Al_2O_3	13.406	13.680	13.676	13.929	14.033	13.971	13.780	13.513	13.980
FeO	18.904	19.704	17.108	17.808	19.202	19.404	17.781	18.053	19.266
MnO	0.271	0.265	0.189	0.270	0.267	0.243	0.248	0.284	0.279
MgO	12.852	12.848	14.395	14.412	13.089	12.510	14.145	13.472	12.694
CaO	0.001	0.055	0.027	0.020	0.010	0.029	0.000	0.000	0.013
Na_2O	0.171	0.112	0.100	0.111	0.174	0.173	0.128	0.047	0.139
K_2O	9.722	9.725	9.728	9.819	9.881	9.889	9.915	9.944	9.949
BaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F_2O	1.420	1.379	1.822	1.402	1.582	1.320	1.258	1.642	1.306
Cl_2O	0.261	0.256	0.070	0.232	0.254	0.268	0.241	0.228	0.239
Total	**96.800**	**95.275**	**98.344**	**98.221**	**98.849**	**96.988**	**97.041**	**97.688**	**98.786**
Si	5.596	5.338	5.610	5.606	5.579	5.516	5.614	5.653	5.603
Ti	0.439	0.412	0.487	0.353	0.421	0.432	0.334	0.424	0.473
Al	2.467	2.559	2.447	2.489	2.528	2.572	2.495	2.458	2.523
AlIV	2.404	2.662	2.390	2.394	2.421	2.484	2.386	2.347	2.397
AlVI	0.064	-0.103	0.057	0.096	0.107	0.088	0.109	0.110	0.126
Fe	2.469	2.616	2.172	2.258	2.455	2.535	2.284	2.330	2.467
Mn	0.036	0.036	0.024	0.035	0.035	0.032	0.032	0.037	0.036
Mg	2.992	3.040	3.259	3.258	2.983	2.913	3.240	3.099	2.898
Ca	0.000	0.009	0.004	0.003	0.002	0.005	0.000	0.000	0.002
Na	0.052	0.034	0.029	0.032	0.052	0.052	0.038	0.014	0.041
K	1.937	1.969	1.885	1.900	1.927	1.971	1.943	1.957	1.943
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**15.989**	**16.013**	**15.918**	**15.935**	**15.980**	**16.028**	**15.981**	**15.972**	**15.987**

Biotite Analyses for Thin Section 2907872B

	Bio 13E	Bio 14C	Bio 11C	Bio 13C	Bio 11E	Bio 3 C	Bio 5C	Bio 10C
SiO_2	36.683	36.456	36.382	35.275	36.106	35.308	36.874	35.676
TiO_2	3.100	2.971	2.683	3.061	2.504	3.438	3.507	2.990
Al_2O_3	13.999	14.154	14.050	13.493	13.625	13.833	13.838	13.859
FeO	17.539	18.110	17.550	17.676	17.244	18.632	18.861	17.787
MnO	0.250	0.291	0.302	0.274	0.278	0.315	0.189	0.341
MgO	14.072	14.208	14.730	13.958	15.120	13.425	13.384	14.381
CaO	0.000	0.014	0.000	0.000	0.011	0.000	0.000	0.025
Na_2O	0.128	0.115	0.121	0.151	0.016	0.148	0.040	0.143
K_2O	9.960	9.975	9.983	10.036	10.087	10.113	10.285	10.033
BaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F_2O	1.263	1.421	1.728	1.422	2.290	1.466	1.493	1.233
Cl_2O	0.206	0.242	0.247	0.248	0.215	0.243	0.274	0.247
Total	**97.321**	**98.067**	**97.970**	**95.736**	**97.654**	**97.085**	**98.866**	**96.799**
Si	5.621	5.551	5.545	5.530	5.540	5.489	5.629	5.497
Ti	0.357	0.340	0.308	0.361	0.289	0.402	0.403	0.346
Al	2.528	2.540	2.524	2.493	2.464	2.534	2.490	2.517
AlIV	2.379	2.449	2.455	2.470	2.460	2.511	2.371	2.503
AlVI	0.149	0.091	0.069	0.023	0.004	0.023	0.119	0.014
Fe	2.247	2.306	2.237	2.317	2.213	2.422	2.408	2.292
Mn	0.033	0.037	0.039	0.036	0.036	0.041	0.024	0.044
Mg	3.214	3.225	3.347	3.262	3.459	3.111	3.046	3.303
Ca	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.004
Na	0.038	0.034	0.036	0.046	0.005	0.045	0.012	0.043
K	1.947	1.938	1.941	2.007	1.975	2.005	2.003	1.972
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**15.985**	**15.974**	**15.977**	**16.053**	**15.981**	**16.050**	**16.015**	**16.019**

Biotite Analyses for Thin Section 2907872B

	Bio 10E	Bio 12C	Bio 12E	Bio Bio
SiO_2	35.695	36.807	36.426	35.310
TiO_2	2.779	2.821	2.863	3.674
Al_2O_3	13.820	13.923	13.882	13.971
FeO	17.256	18.134	18.061	19.404
MnO	0.305	0.311	0.291	0.243
MgO	14.520	14.258	14.092	12.510
CaO	0.013	0.000	0.000	0.029
Na_2O	0.121	0.082	0.074	0.173
K_2O	10.014	10.025	10.030	9.889
BaO	0.000	0.016	0.000	0.000
F_2O	1.990	1.821	1.563	1.320
Cl_2O	0.235	0.240	0.234	0.268
Total	**96.919**	**98.660**	**97.713**	**96.988**
Si	5.528	5.600	5.586	5.516
Ti	0.324	0.323	0.330	0.432
Al	2.522	2.497	2.509	2.572
AlIV	2.472	2.400	2.414	2.484
AlVI	0.050	0.096	0.095	0.088
Fe	2.235	2.307	2.316	2.535
Mn	0.040	0.040	0.038	0.032
Mg	3.352	3.234	3.221	2.913
Ca	0.002	0.000	0.000	0.005
Na	0.036	0.024	0.022	0.052
K	1.978	1.946	1.962	1.971
Ba	0.000	0.000	0.000	0.000
Total	**16.017**	**15.970**	**15.984**	**16.028**

Biotite Analyses for Thin Section 2907875B

	Bio 3C	Bio 2C	Bio 8E	Bio 1C	Bio 11E	Bio 1E	Bio 10E	Bio 12E
SiO_2	32.794	32.772	33.123	34.638	35.451	34.028	34.007	33.038
TiO_2	3.835	3.964	3.867	3.999	3.956	4.157	4.031	3.899
Al_2O_3	15.004	15.095	15.873	14.672	15.080	15.169	15.452	14.171
FeO	21.473	22.022	21.497	21.245	19.944	21.351	21.776	18.965
MnO	0.433	0.467	0.448	0.469	0.475	0.405	0.426	0.208
MgO	10.212	10.305	10.281	9.613	9.152	9.983	9.849	12.013
CaO	0.029	0.024	0.091	0.059	0.248	0.045	0.000	0.014
Na_2O	0.086	0.000	0.146	0.000	0.117	0.047	0.014	0.000
K_2O	8.068	8.484	8.861	9.020	9.290	9.485	9.581	9.838
BaO								
F	0.833	0.902	0.605	0.702	1.066	1.168	0.770	0.921
Cl	0.074	0.064	0.087	0.065	0.032	0.072	0.079	0.038
Total	**92.877**	**94.184**	**94.941**	**94.589**	**94.939**	**95.937**	**96.034**	**93.220**
Si	5.283	5.231	5.244	5.546	5.710	5.407	5.379	5.340
Ti	0.465	0.476	0.461	0.482	0.479	0.497	0.480	0.474
Al	2.849	2.839	2.962	2.769	2.862	2.840	2.881	2.699
AlIV	2.717	2.769	2.756	2.454	2.290	2.593	2.621	2.660
AlVI	0.131	0.070	0.206	0.315	0.572	0.247	0.260	0.039
Fe	2.893	2.939	2.846	2.845	2.686	2.837	2.881	2.564
Mn	0.059	0.063	0.060	0.064	0.065	0.055	0.057	0.028
Mg	2.452	2.452	2.427	2.295	2.197	2.365	2.322	2.894
Ca	0.005	0.004	0.015	0.010	0.043	0.008	0.000	0.002
Na	0.027	0.000	0.045	0.000	0.037	0.015	0.004	0.000
K	1.658	1.727	1.790	1.843	1.909	1.923	1.934	2.029
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**15.690**	**15.731**	**15.850**	**15.853**	**15.988**	**15.945**	**15.938**	**16.031**

Biotite Analyses for Thin Section 2907875B

	Bio 11C	Bio 10C	Bio 5C	Bio 9C	Bio 6C	Bio 8C
SiO_2	35.201	31.750	31.615	31.880	31.243	31.996
TiO_2	4.274	4.371	3.682	4.731	4.891	4.294
Al_2O_3	13.906	14.834	15.709	15.031	15.849	15.027
FeO	20.945	21.105	21.628	21.716	20.984	21.540
MnO	0.301	0.376	0.458	0.347	0.380	0.400
MgO	10.547	9.930	10.130	9.233	9.179	9.729
CaO	0.022	0.000	0.000	0.000	0.004	0.000
Na_2O	0.000	0.009	0.000	0.000	0.019	0.000
K_2O	9.840	9.857	9.886	9.967	9.979	10.015
BaO						
F	1.012	1.098	0.929	0.375	1.058	0.841
Cl	0.052	0.077	0.079	0.070	0.055	0.067
Total	**96.303**	**93.480**	**94.220**	**93.462**	**93.667**	**93.976**
Si	5.581	5.212	5.118	5.228	5.137	5.221
Ti	0.510	0.540	0.448	0.584	0.605	0.527
Al	2.599	2.870	2.997	2.905	3.071	2.890
AlIV	2.419	2.788	2.882	2.772	2.863	2.779
AlVI	0.180	0.081	0.116	0.133	0.207	0.111
Fe	2.777	2.897	2.928	2.978	2.885	2.939
Mn	0.040	0.052	0.063	0.048	0.053	0.055
Mg	2.493	2.430	2.445	2.257	2.250	2.367
Ca	0.004	0.000	0.000	0.000	0.001	0.000
Na	0.000	0.003	0.000	0.000	0.006	0.000
K	1.990	2.064	2.042	2.085	2.093	2.085
Ba	0.000	0.000	0.000	0.000	0.000	0.000
Total	**15.994**	**16.067**	**16.042**	**16.085**	**16.100**	**16.085**

Biotite Analyses for Thin Section 2907875C

	Bio 1	Bio 2	Bio 3
SiO_2	33.502	34.687	34.910
TiO_2	5.389	5.606	5.180
Al_2O_3	13.721	13.345	13.498
FeO	22.384	22.534	22.512
MnO	0.079	0.059	0.080
MgO	9.668	9.761	9.757
CaO	0.000	0.001	0.000
Na_2O	0.000	0.000	0.019
K_2O	9.766	9.869	9.980
BaO	0.000	0.000	0.000
F	0.664	0.434	0.203
Cl	0.076	0.083	0.089
Total	**95.256**	**96.391**	**96.306**
Si	5.396	5.514	5.544
Ti	0.653	0.670	0.619
Al	2.605	2.500	2.526
AlIV	2.604	2.486	2.456
AlVI	0.000	0.014	0.071
Fe	3.015	2.995	2.990
Mn	0.011	0.008	0.011
Mg	2.321	2.313	2.310
Ca	0.000	0.000	0.000
Na	0.000	0.000	0.006
K	2.007	2.001	2.022
Ba	0.000	0.000	0.000
Total	**16.007**	**16.002**	**16.028**

Biotite Analyses for Thin Section 2907885B

	Bio 4E	Bio 1C 1	Bio 1C	Bio 4C	Bio 1E	Bio 3C	Bio 1E 1	Bio 2C	Bio 3C
SiO_2	37.128	35.879	35.470	37.062	36.848	36.809	36.553	36.944	36.809
TiO_2	3.619	4.563	4.521	4.463	4.306	4.853	4.429	4.268	4.853
Al_2O_3	14.016	13.413	13.646	13.574	13.345	13.546	13.279	13.676	13.546
FeO	17.849	16.937	17.810	16.665	17.922	17.534	16.665	17.108	17.534
MnO	0.130	0.223	0.216	0.252	0.214	0.217	0.227	0.189	0.217
MgO	13.707	14.386	13.701	14.762	13.614	13.787	13.971	14.395	13.787
CaO	0.078	0.000	0.011	0.000	0.027	0.000	0.020	0.027	0.000
Na_2O	0.921	0.102	0.193	0.092	0.182	0.062	0.096	0.100	0.062
K_2O	8.011	10.101	10.161	10.221	10.230	10.269	10.314	9.728	10.269
BaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	0.852	1.707	1.483	1.427	1.674	1.446	1.329	1.822	1.446
Cl	0.087	0.071	0.092	0.088	0.094	0.092	0.084	0.070	0.092
Total	**96.398**	**97.406**	**97.318**	**98.678**	**98.547**	**98.615**	**96.967**	**98.344**	**98.615**
Si	5.660	5.525	5.490	5.605	5.651	5.612	5.655	5.610	5.612
Ti	0.415	0.528	0.526	0.508	0.497	0.557	0.515	0.487	0.557
Al	2.518	2.434	2.489	2.419	2.412	2.434	2.421	2.447	2.434
AlIV	2.340	2.475	2.510	2.395	2.349	2.388	2.345	2.390	2.388
AlVI	0.178	-0.041	-0.021	0.024	0.064	0.046	0.076	0.057	0.046
Fe	2.275	2.181	2.305	2.108	2.299	2.236	2.156	2.172	2.236
Mn	0.017	0.029	0.028	0.032	0.028	0.028	0.030	0.024	0.028
Mg	3.115	3.302	3.161	3.328	3.113	3.134	3.222	3.259	3.134
Ca	0.013	0.000	0.002	0.000	0.004	0.000	0.003	0.004	0.000
Na	0.272	0.031	0.058	0.027	0.054	0.018	0.029	0.029	0.018
K	1.558	1.984	2.006	1.972	2.002	1.997	2.036	1.885	1.997
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**15.843**	**16.015**	**16.066**	**15.999**	**16.060**	**16.016**	**16.068**	**15.918**	**16.016**

Biotite Analyses for Thin Section 2907885B

	Bio 1E	Bio 1C
SiO_2	35.917	36.352
TiO_2	4.995	5.284
Al_2O_3	13.309	13.504
FeO	17.634	15.937
MnO	0.090	0.150
MgO	13.255	13.973
CaO	0.025	0.014
Na_2O	0.115	0.108
K_2O	10.173	10.325
BaO	0.000	0.000
F	1.609	1.075
Cl	0.070	0.060
Total	**97.192**	**96.780**
Si	5.591	5.622
Ti	0.585	0.615
Al	2.442	2.461
AlIV	2.409	2.378
AlVI	0.032	0.083
Fe	2.295	2.061
Mn	0.012	0.020
Mg	3.076	3.221
Ca	0.004	0.002
Na	0.035	0.032
K	2.020	2.037
Ba	0.000	0.000
Total	**15.999**	**16.059**

Biotite Analyses for Thin Section 2907885C

	Bio 2	Bio	Bio 4	Bio 3 1	Bio 2 1	Bio 1	Bio 3	Bio 2 2	Bio 2
SiO_2	36.343	35.273	36.730	36.253	37.010	34.805	37.220	36.829	36.844
TiO_2	4.730	4.610	4.731	4.795	4.186	4.039	4.616	4.209	4.288
Al_2O_3	13.228	11.615	13.430	13.147	13.158	13.336	13.489	12.973	13.328
FeO	16.490	15.963	16.666	16.634	15.762	16.274	16.633	15.964	15.693
MnO	0.221	0.182	0.230	0.231	0.200	0.173	0.178	0.212	0.192
MgO	13.251	14.067	14.248	14.291	14.822	14.714	14.220	14.774	14.508
CaO	0.034	0.025	0.008	0.001	0.000	0.000	0.010	0.000	0.000
Na_2O	0.059	0.051	0.104	0.080	0.147	0.116	0.093	0.125	0.097
K_2O	10.033	10.068	9.537	9.801	9.913	9.956	9.979	9.984	10.057
BaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	1.726	1.904	1.291	1.726	1.785	1.473	1.755	1.566	1.351
Cl	0.071	0.078	0.082	0.087	0.079	0.061	0.073	0.092	0.089
Total	**96.195**	**93.878**	**97.061**	**97.046**	**97.093**	**94.998**	**98.305**	**96.786**	**96.532**
Si	5.703	5.682	5.621	5.592	5.687	5.459	5.673	5.676	5.688
Ti	0.558	0.559	0.545	0.556	0.484	0.477	0.529	0.488	0.498
Al	2.446	2.205	2.422	2.390	2.383	2.465	2.423	2.356	2.425
AlIV	2.297	2.318	2.379	2.408	2.313	2.541	2.327	2.324	2.312
AlVI	0.149	-0.112	0.043	-0.018	0.070	-0.075	0.096	0.032	0.112
Fe	2.164	2.151	2.133	2.146	2.025	2.135	2.120	2.058	2.026
Mn	0.029	0.025	0.030	0.030	0.026	0.023	0.023	0.028	0.025
Mg	3.100	3.378	3.250	3.286	3.395	3.441	3.231	3.394	3.339
Ca	0.006	0.004	0.001	0.000	0.000	0.000	0.002	0.000	0.000
Na	0.018	0.016	0.031	0.024	0.044	0.035	0.027	0.037	0.029
K	2.008	2.069	1.862	1.929	1.943	1.992	1.940	1.963	1.981
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**16.032**	**16.090**	**15.894**	**15.953**	**15.987**	**16.028**	**15.970**	**16.000**	**16.010**

APPENDIX C

MICROPROBE ANALYSES FOR FELDSPARS

Feldspar Analyses for Thin Section 2907872B

	Fel 1	Fel 10	Fel 11	Fel 12	Fel 13	Fel 14	Fel 15	Fel 16	Fel 17	Fel 18
SiO_2	62.098	61.057	60.006	61.397	60.477	60.918	59.974	59.503	58.586	60.143
Al_2O_3	24.948	24.797	23.860	24.348	23.992	24.072	23.573	23.940	23.579	24.489
Sr_2O_5	0.000	0.000	0.000	0.000	0.000	0.068	0.000	0.000	0.000	0.000
CaO	5.440	5.162	5.201	5.274	5.261	5.192	5.108	5.325	5.229	5.208
FeO	0.095	0.107	0.051	0.069	0.062	0.064	0.067	0.127	0.072	0.087
BaO	0.087	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000
Na_2O	8.534	8.546	8.547	8.690	8.583	8.826	8.566	8.419	8.396	8.543
K_2O	0.254	0.116	0.228	0.183	0.249	0.208	0.205	0.219	0.231	0.201
Total	**100.096**	**101.457**	**99.784**	**97.894**	**99.961**	**98.624**	**99.349**	**97.506**	**97.534**	**96.093**
Mole Prop.	3.041	2.995	2.934	2.998	2.955	2.975	2.923	2.920	2.876	2.957
# Anions	5.006	5.007	5.021	5.015	5.020	5.031	5.019	5.022	5.028	5.020
An	25.678	24.858	24.837	24.854	24.947	24.249	24.496	25.575	25.262	24.909
Or	1.428	0.663	1.295	1.027	1.408	1.159	1.169	1.254	1.330	1.146
Ab	72.894	74.479	73.868	74.118	73.646	74.593	74.335	73.171	73.408	73.946

Feldspar Analyses for Thin Section 2907872B

	Fel 19	Fel 2	Fel 20	Fel 21	Fel 22	Fel 23	Fel 24	Fel 25	Fel 26	Fel 27
SiO_2	59.437	63.282	59.525	61.155	61.752	61.042	61.313	59.946	61.151	61.333
Al_2O_3	23.632	24.684	24.253	24.217	24.412	24.688	24.401	24.306	24.637	24.234
Sr_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	5.208	5.136	5.510	5.323	5.264	5.206	5.405	5.205	5.149	5.180
FeO	0.085	0.021	0.104	0.015	0.049	0.100	0.026	0.095	0.064	0.087
BaO	0.049	0.248	0.000	0.000	0.000	0.025	0.099	0.000	0.198	0.000
Na_2O	8.556	8.756	8.388	8.685	8.405	8.902	8.355	8.558	8.697	8.589
K_2O	0.245	0.223	0.288	0.216	0.179	0.116	0.229	0.205	0.195	0.217
Total	**98.672**	**97.211**	**102.350**	**98.069**	**99.611**	**100.060**	**100.078**	**99.828**	**98.316**	**100.091**
Mole Prop.	2.909	3.070	2.934	2.986	3.006	2.998	2.994	2.945	2.997	2.990
# Anions	5.029	4.999	5.026	5.018	4.993	5.029	5.000	5.023	5.018	5.009
An	24.821	24.174	26.197	24.993	25.445	24.269	25.990	24.861	24.380	24.688
Or	1.388	1.249	1.630	1.206	1.033	0.642	1.310	1.165	1.100	1.230
Ab	73.791	74.577	72.173	73.801	73.522	75.090	72.699	73.974	74.520	74.082

Feldspar Analyses for Thin Section 2907872B

	Fel 28	Fel 29	Fel 3	Fel 4	Fel 5	Fel 6	Fel 7	Fel 8	Fel 9
SiO_2	61.484	58.851	62.456	62.092	61.594	61.508	61.713	61.917	59.108
Al_2O_3	24.854	23.949	24.423	24.436	24.512	23.998	24.510	24.639	24.217
Sr_2O_5	0.000	0.012	0.045	0.000	0.080	0.000	0.000	0.000	0.000
CaO	5.454	5.176	5.253	5.404	5.013	5.104	5.163	5.283	5.432
FeO	0.120	0.057	0.093	0.112	0.225	0.094	0.100	0.114	0.046
BaO	0.000	0.000	0.000	0.000	0.087	0.000	0.185	0.112	0.000
Na_2O	8.535	8.364	8.601	8.484	8.449	8.628	8.693	8.828	8.267
K_2O	0.148	0.187	0.366	0.231	0.090	0.171	0.217	0.202	0.239
Total	**99.640**	**100.596**	**96.595**	**101.237**	**100.759**	**100.051**	**99.504**	**100.582**	**101.095**
Mole Prop.	3.017	2.894	3.036	3.024	3.003	2.987	3.013	3.028	2.914
# Anions	5.009	5.022	5.007	5.000	4.998	5.005	5.013	5.020	5.020
An	25.878	25.205	24.714	25.693	24.562	24.397	24.409	24.574	26.270
Or	0.837	1.083	2.051	1.309	0.527	0.973	1.220	1.121	1.373
Ab	73.285	73.712	73.235	72.998	74.911	74.630	74.371	74.305	72.356

Feldspar Analyses for Thin Section 2907875B

	Fel	Fel	Fel 1	Fel 10	Fel 11	Fel 12	Fel 13	Fel 14	Fel 15	Fel 16	Fel 17
SiO_2	59.029	58.896	57.371	59.200	59.959	59.298	58.346	59.529	59.394	59.029	58.750
Al_2O_3	24.744	25.468	26.042	24.892	24.845	24.999	24.777	25.404	24.952	25.119	25.154
Sr_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	5.996	6.389	6.848	6.086	5.948	5.977	5.949	6.408	6.138	6.344	6.221
FeO	0.109	0.050	0.124	0.091	0.099	0.121	0.162	0.152	0.160	0.149	0.114
BaO	0.000	0.000	0.000	0.000	0.144	0.048	0.000	0.119	0.012	0.132	0.036
Na_2O	7.855	7.604	7.232	7.795	7.931	7.577	7.612	7.404	7.603	7.147	7.259
K_2O	0.332	0.373	0.383	0.342	0.294	0.576	0.612	0.650	0.650	0.705	0.616
Total	**98.065**	**98.780**	**97.999**	**98.407**	**99.220**	**98.597**	**97.458**	**99.667**	**98.910**	**98.624**	**98.150**
Mole Prop.	2.932	2.952	2.921	2.943	2.967	2.947	2.909	2.973	2.953	2.943	2.933
# Anions	5.012	5.009	5.015	5.009	5.005	5.003	5.017	5.003	5.009	4.993	4.996
An	29.097	31.023	33.582	29.546	28.803	29.338	29.088	31.136	29.696	31.537	30.966
Or	1.921	2.159	2.237	1.977	1.695	3.365	3.562	3.763	3.747	4.171	3.648
Ab	68.982	66.818	64.181	68.477	69.503	67.297	67.349	65.102	66.557	64.293	65.386

Feldspar Analyses for Thin Section 2907875B

	Fel 18	Fel 19	Fel 2	Fel 20	Fel 21	Fel 22	Fel 23	Fel 24	Fel 25	Fel 3	Fel 4
SiO_2	58.994	58.449	57.651	58.350	58.740	58.222	58.742	59.927	59.491	56.575	56.893
Al_2O_3	25.307	25.113	25.827	25.555	25.782	26.264	24.270	24.947	25.041	26.192	26.830
Sr_2O_5	0.000	0.000	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	6.442	6.467	7.014	6.747	7.119	7.071	5.809	6.440	6.211	7.600	7.624
FeO	0.165	0.068	0.033	0.194	0.154	0.187	1.729	0.202	0.042	0.000	0.053
BaO	0.144	0.000	0.012	0.000	0.073	0.000	0.132	0.036	0.084	0.000	0.000
Na_2O	7.202	7.193	7.293	7.150	7.022	7.152	7.264	7.344	7.495	7.026	6.903
K_2O	0.681	0.681	0.341	0.581	0.560	0.575	0.655	0.623	0.628	0.455	0.375
Total	**98.935**	**97.970**	**98.226**	**98.577**	**99.449**	**99.470**	**98.602**	**99.518**	**98.991**	**97.848**	**98.678**
Mole Prop.	2.950	2.924	2.928	2.939	2.963	2.961	2.923	2.972	2.957	2.908	2.936
# Anions	4.999	5.002	5.017	5.005	4.999	5.014	5.012	4.993	5.001	5.028	5.016
An	31.756	31.868	34.022	33.112	34.740	34.164	29.437	31.461	30.267	36.442	37.079
Or	3.995	3.993	1.969	3.393	3.254	3.305	3.953	3.622	3.641	2.599	2.169
Ab	64.249	64.139	64.010	63.496	62.005	62.531	66.609	64.917	66.092	60.959	60.752

Feldspar Analyses for Thin Section 2907875B

	Fel 5	Fel 6	Fel 8	Fel 9
SiO_2	56.423	58.975	59.779	59.649
Al_2O_3	26.613	25.103	25.051	24.731
Sr_2O_5	0.000	0.000	0.000	0.000
CaO	7.564	5.987	6.033	5.895
FeO	0.033	0.157	0.045	0.073
BaO	0.000	0.023	0.000	0.000
Na_2O	6.788	7.999	7.768	7.596
K_2O	0.467	0.330	0.367	0.454
Total	**97.889**	**98.575**	**99.044**	**98.398**
Mole Prop.	2.911	2.944	2.965	2.947
# Anions	5.016	5.023	5.001	4.992
An	37.070	28.708	29.390	29.210
Or	2.727	1.884	2.131	2.679
Ab	60.203	69.407	68.479	68.111

Feldspar Analyses for Thin Section 2907875C

	Fel 1	Fel 10	Fel 11	Fel 12	Fel 13	Fel 14	Fel 15	Fel 16	Fel 17	Fel 18
SiO_2	56.742	56.352	58.382	57.771	58.102	51.100	58.693	57.567	57.146	58.648
Al_2O_3	25.307	25.553	25.903	25.721	25.944	26.041	26.237	25.825	25.855	26.284
Sr_2O_5	0.000	0.000	0.047	0.057	0.000	0.000	0.000	0.000	0.000	0.000
CaO	7.328	7.738	7.308	7.677	7.577	8.735	7.533	7.465	7.536	7.556
FeO	0.090	0.135	0.085	0.156	0.105	5.223	0.069	0.080	0.174	0.085
BaO	0.112	0.272	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000
Na_2O	6.981	5.775	6.844	6.837	6.958	4.955	6.787	6.803	6.914	6.838
K_2O	0.404	2.377	0.564	0.504	0.560	0.378	0.597	0.538	0.602	0.578
Total	**96.963**	**98.202**	**99.132**	**98.722**	**99.247**	**96.457**	**99.917**	**98.279**	**98.227**	**99.989**
Mole Prop.	2.883	2.888	2.955	2.936	2.953	2.780	2.977	2.926	2.918	2.978
# Anions	5.015	5.035	4.996	5.008	5.010	5.059	4.994	5.003	5.020	4.998
An	35.847	36.815	35.888	37.180	36.364	48.121	36.700	36.561	36.293	36.645
Or	2.350	13.464	3.296	2.903	3.201	2.481	3.466	3.140	3.454	3.339
Ab	61.803	49.721	60.816	59.916	60.435	49.398	59.834	60.299	60.253	60.017

Feldspar Analyses for Thin Section 2907875C

	Fel 18A	Fel 19	Fel 2	Fel 20	Fel 21	Fel 21A	Fel 22	Fel 23	Fel 24	Fel 25
SiO_2	58.494	58.466	58.566	57.837	58.353	56.267	58.224	58.333	58.382	59.411
Al_2O_3	25.976	26.177	26.248	26.186	26.099	24.419	26.273	26.203	26.271	26.116
Sr_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.080	0.068
CaO	7.574	7.623	7.491	7.651	7.459	7.031	7.607	7.393	7.613	7.218
FeO	0.120	0.151	0.072	0.145	0.197	1.948	0.109	0.163	0.171	0.093
BaO	0.012	0.025	0.099	0.075	0.075	0.124	0.049	0.075	0.112	0.063
Na_2O	6.858	6.581	7.050	7.008	6.931	6.845	6.827	6.982	6.869	7.094
K_2O	0.607	0.599	0.444	0.557	0.622	0.582	0.581	0.613	0.597	0.534
Total	**99.641**	**99.620**	**99.972**	**99.459**	**99.735**	**97.215**	**99.671**	**99.844**	**100.096**	**100.598**
Mole Prop.	2.966	2.967	2.976	2.954	2.965	2.862	2.965	2.969	2.975	2.999
# Anions	5.002	4.987	5.006	5.019	5.008	5.038	5.004	5.012	5.009	4.999
An	36.575	37.654	36.054	36.440	35.961	34.962	36.833	35.615	36.680	34.885
Or	3.491	3.521	2.547	3.156	3.568	3.445	3.347	3.517	3.427	3.071
Ab	59.935	58.825	61.399	60.404	60.471	61.594	59.820	60.868	59.892	62.044

Feldspar Analyses for Thin Section 2907875C

	Fel 26	Fel 27	Fel 28	Fel 28A	Fel 29	Fel 29 1	Fel 3	Fel 4	Fel 5	Fel 6
SiO_2	56.996	57.276	57.989	58.658	58.802	56.130	57.529	58.047	58.616	58.057
Al_2O_3	25.411	25.971	26.065	26.173	26.666	25.445	25.651	26.292	25.886	25.699
Sr_2O_5	0.000	0.000	0.000	0.000	0.047	0.000	0.000	0.000	0.000	0.000
CaO	7.304	7.441	7.462	7.535	7.718	7.557	7.437	7.813	7.305	7.396
FeO	0.064	0.075	0.046	0.148	0.138	0.072	0.087	0.051	0.156	0.163
BaO	0.000	0.025	0.000	0.099	0.049	0.049	0.000	0.037	0.037	0.037
Na_2O	6.999	6.972	6.702	6.885	6.589	6.725	6.873	6.734	6.961	6.935
K_2O	0.501	0.564	0.679	0.628	0.578	0.430	0.411	0.438	0.513	0.465
Total	**97.275**	**98.323**	**98.944**	**100.126**	**100.586**	**96.408**	**97.988**	**99.413**	**99.473**	**98.752**
Mole Prop.	2.895	2.923	2.947	2.978	2.996	2.867	2.919	2.960	2.964	2.940
# Anions	5.016	5.018	4.998	5.003	4.988	5.011	5.002	4.998	4.999	5.003
An	35.515	35.897	36.580	36.326	37.964	37.339	36.519	38.072	35.613	36.079
Or	2.901	3.238	3.965	3.602	3.386	2.530	2.402	2.544	2.978	2.701
Ab	61.584	60.864	59.455	60.072	58.650	60.131	61.079	59.384	61.409	61.221

Feldspar Analyses for Thin Section 2907875C

	Fel 7	Fel 7A	Fel 7B	Fel 8	Fel 8A
SiO_2	58.327	57.403	58.755	57.424	58.263
Al_2O_3	25.931	25.893	25.878	25.307	26.148
Sr_2O_5	0.000	0.023	0.000	0.000	0.000
CaO	7.484	7.402	7.308	7.462	7.781
FeO	0.087	0.085	0.103	0.102	0.117
BaO	0.099	0.012	0.000	0.000	0.000
Na_2O	6.888	6.915	6.978	6.790	6.879
K_2O	0.518	0.489	0.304	0.422	0.569
Total	**99.335**	**98.222**	**99.326**	**97.506**	**99.756**
Mole Prop.	2.957	2.924	2.965	2.905	2.967
# Anions	5.001	5.010	4.989	4.998	5.008
An	36.392	36.110	36.004	36.848	37.219
Or	2.999	2.841	1.781	2.479	3.238
Ab	60.610	61.049	62.215	60.674	59.543

Feldspar Analyses for Thin Section 2907885B

	Fel	Fel 1	Fel 10	Fel 11	Fel 12	Fel 13	Fel 14	Fel 15	Fel 16	Fel 17
SiO_2	61.234	61.630	60.851	61.099	61.564	60.171	61.221	61.373	60.597	60.319
Al_2O_3	23.849	23.666	24.196	24.191	24.023	24.661	24.537	24.401	24.438	24.640
Sr_2O_5	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079
CaO	5.131	5.083	5.281	5.265	5.191	5.293	5.167	5.111	5.134	5.237
FeO	0.089	0.048	0.042	0.078	0.078	0.068	0.170	0.126	0.048	0.129
BaO	0.215	0.071	0.012	0.048	0.000	0.071	0.000	0.000	0.167	0.144
Na_2O	8.457	8.500	8.294	8.244	8.411	8.681	8.630	8.475	8.322	8.355
K_2O	0.153	0.325	0.325	0.436	0.195	0.194	0.264	0.292	0.359	0.219
Total	**99.162**	**99.323**	**99.002**	**99.362**	**99.462**	**99.140**	**99.988**	**99.777**	**99.065**	**99.121**
Mole Prop.	2.973	2.981	2.970	2.979	2.988	2.967	2.997	2.994	2.968	2.968
# Anions	5.000	5.001	5.002	5.001	4.994	5.030	5.016	5.004	5.007	5.012
An	24.886	24.377	25.538	25.432	25.145	24.929	24.492	24.580	24.895	25.402
Or	0.883	1.857	1.873	2.508	1.125	1.087	1.489	1.669	2.073	1.266
Ab	74.230	73.766	72.589	72.061	73.730	73.984	74.019	73.751	73.033	73.332

Feldspar Analyses for Thin Section 2907885B

	Fel 18	Fel 19	Fel 2	Fel 20	Fel 21	Fel 22	Fel 23	Fel 24	Fel 3	Fel 4	Fel 5
SiO_2	61.758	60.079	60.980	60.025	60.515	60.428	61.149	59.931	58.727	60.224	59.850
Al_2O_3	24.278	24.644	24.455	24.633	24.452	24.147	24.599	24.357	23.448	24.563	24.554
Sr_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	5.181	5.250	5.104	5.149	5.163	5.187	5.108	5.197	5.019	5.155	5.171
FeO	0.078	0.076	0.078	0.157	0.076	0.096	0.018	0.111	0.185	0.071	0.091
BaO	0.036	0.000	0.000	0.012	0.000	0.023	0.000	0.000	0.000	0.023	0.000
Na_2O	8.779	8.472	8.361	8.488	8.384	8.634	8.684	8.802	8.285	8.135	8.543
K_2O	0.264	0.440	0.400	0.245	0.231	0.183	0.165	0.428	0.287	0.267	0.407
Total	**100.375**	**98.961**	**99.379**	**98.709**	**98.821**	**98.699**	**99.723**	**98.825**	**95.951**	**98.439**	**98.617**
Mole Prop.	3.009	2.961	2.981	2.957	2.965	2.958	2.993	2.953	2.874	2.955	2.951
# Anions	5.017	5.027	5.006	5.020	5.007	5.021	5.013	5.047	5.019	4.997	5.031
An	24.231	24.875	24.645	24.754	25.050	24.666	24.304	24.020	24.660	25.525	24.490
Or	1.469	2.480	2.299	1.400	1.336	1.037	0.935	2.353	1.677	1.577	2.296
Ab	74.300	72.644	73.056	73.846	73.614	74.298	74.761	73.627	73.663	72.898	73.214

Feldspar Analyses for Thin Section 2907885B

	Fel 6	Fel 7	Fel 8	Fel 9
SiO_2	60.973	61.087	60.819	60.500
Al_2O_3	24.261	24.393	24.459	24.591
Sr_2O_5	0.000	0.000	0.000	0.000
CaO	4.998	4.444	5.288	5.080
FeO	0.099	0.102	0.086	0.147
BaO	0.071	0.000	0.012	0.071
Na_2O	8.727	8.545	8.440	8.427
K_2O	0.314	0.292	0.206	0.318
Total	**99.443**	**98.861**	**99.310**	**99.136**
Mole Prop.	2.979	2.973	2.979	2.970
# Anions	5.022	4.999	5.008	5.013
An	23.615	21.941	25.414	24.532
Or	1.769	1.714	1.179	1.828
Ab	74.617	76.345	73.407	73.640

Feldspar Analyses for Thin Section 2907885C

	Fel 1	Fel 11	Fel 13	Fel 13A	Fel 14	Fel 15	Fel 15C	Fel 16	Fel 16A	Fel 17
SiO_2	60.888	60.361	59.617	65.924	59.809	62.270	51.346	59.882	61.506	59.968
Al_2O_3	24.316	24.206	23.815	19.841	23.904	24.138	28.729	24.223	24.633	23.845
Sr_2O_5	0.057	0.080	0.125	0.000	0.000	0.000	0.000	0.035	0.000	0.000
CaO	5.430	5.149	5.440	0.274	5.404	4.104	13.923	5.297	5.618	5.303
FeO	0.148	0.114	0.102	0.018	0.018	0.085	0.636	0.008	0.031	0.098
BaO	0.173	0.025	0.000	0.037	0.061	0.000	0.000	0.049	0.000	0.000
Na_2O	8.109	8.240	8.046	11.041	8.190	9.308	5.207	8.345	8.148	8.360
K_2O	0.373	0.399	0.201	0.080	0.379	0.305	0.087	0.270	0.352	0.338
Total	**99.494**	**98.574**	**97.346**	**97.215**	**97.766**	**100.209**	**99.928**	**98.109**	**100.288**	**97.912**
Mole Prop.	2.979	2.955	2.919	2.963	2.928	3.011	2.897	2.940	3.008	2.933
# Anions	5.000	5.008	5.002	4.995	5.011	5.025	5.096	5.015	4.994	5.017
An	26.425	25.074	26.878	1.348	26.134	19.258	59.375	25.566	27.032	25.453
Or	2.164	2.312	1.183	0.465	2.185	1.703	0.440	1.550	2.015	1.934
Ab	71.411	72.614	71.939	98.187	71.681	79.040	40.184	72.884	70.953	72.613

Feldspar Analyses for Thin Section 2907885C

	Fel 18	Fel 19	Fel 2	Fel 20	Fel 21	Fel 22A	Fel 23	Fel 24	Fel 24A	Fel 25
SiO_2	60.321	62.210	60.843	61.416	61.262	59.702	61.093	59.724	61.596	60.361
Al_2O_3	23.974	18.473	23.851	24.100	24.699	24.181	24.257	24.763	23.418	23.836
Sr_2O_5	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000
CaO	5.383	0.008	5.225	4.892	5.164	5.197	5.432	6.289	4.836	5.346
FeO	0.138	0.073	0.049	0.013	0.093	0.082	0.130	0.105	0.327	0.059
BaO	0.025	0.608	0.000	0.186	0.061	0.037	0.061	0.037	0.012	0.124
Na_2O	8.157	0.435	7.966	8.727	8.917	8.256	8.193	7.856	8.609	8.409
K_2O	0.305	16.168	0.345	0.133	0.373	0.269	0.378	0.169	0.187	0.352
Total	**98.300**	**97.977**	**98.278**	**99.478**	**100.570**	**97.724**	**99.544**	**98.943**	**98.985**	**98.487**
Mole Prop.	2.947	2.799	2.953	2.985	3.008	2.929	2.983	2.959	2.972	2.947
# Anions	5.001	5.032	4.981	5.008	5.037	5.010	5.000	5.003	5.000	5.016
An	26.250	0.042	26.056	23.470	23.750	25.402	26.230	30.374	23.431	25.481
Or	1.770	96.028	2.046	0.757	2.045	1.563	2.175	0.970	1.077	1.996
Ab	71.981	3.930	71.898	75.773	74.206	73.034	71.596	68.656	75.492	72.523

Feldspar Analyses for Thin Section 2907885C

	Fel 26	Fel 27	Fel 28	Fel 30	Fel 4	Fel 4A	Fel 5	Fel 6	Fel 7	Fel 8	Fel 9
SiO_2	61.484	95.915	61.168	60.085	60.659	60.997	60.791	60.644	60.749	58.772	59.764
Al_2O_3	24.000	0.045	24.427	23.864	23.605	23.747	23.783	23.705	23.584	24.748	23.836
Sr_2O_5	0.000	0.000	0.000	0.080	0.000	0.000	0.149	0.068	0.000	0.115	0.000
CaO	5.309	0.014	5.197	5.338	5.444	5.398	5.225	5.199	5.356	6.081	5.282
FeO	0.108	0.033	0.082	0.100	0.163	0.090	0.093	0.104	0.059	0.112	0.135
BaO	0.061	0.000	0.000	0.112	0.025	0.000	0.000	0.037	0.025	0.148	0.000
Na_2O	8.124	0.000	8.357	8.258	7.976	8.053	8.173	8.144	8.194	8.033	8.318
K_2O	0.457	0.000	0.229	0.355	0.239	0.304	0.442	0.385	0.349	0.993	0.431
Total	**99.543**	**96.008**	**99.460**	**98.192**	**98.110**	**98.588**	**98.655**	**98.288**	**98.316**	**99.001**	**97.767**
Mole Prop.	2.986	3.195	2.986	2.939	2.945	2.960	2.958	2.948	2.949	2.939	2.926
# Anions	4.991	4.001	4.998	5.013	4.984	4.986	5.002	4.997	4.998	5.058	5.020
An	25.827	######	25.235	25.782	27.003	26.550	25.436	25.491	26.000	27.896	25.335
Or	2.645	0.000	1.323	2.044	1.408	1.778	2.563	2.250	2.019	5.421	2.463
Ab	71.528	0.000	73.442	72.175	71.588	71.673	72.002	72.258	71.981	66.683	72.202

APPENDIX D

THIN SECTION DESCRIPTIONS

DESCRIPTION OF THIN SECTIONS*

2907872B

This thin section represents the low grade metamorphic zone. The dominant minerals are hornblende (40%) and biotite (30%), but quartz, perthite, plagioclase, sericite, and accessory minerals, such as ilmenite and zircon, are also present. Hornblende-biotite intergrowth is present. Some alteration of hornblende into ilmenite and plagioclase into sericite also can be seen.

2907875B

This sample was collected at the transition zone between the two metamorphic facies. It is well foliated. The sample consists of almost 50% quartz that is present in long ribbons with abundant linear fluid inclusions. The other dominant mineral is plagioclase, which makes up approximately 25% of the sample. The plagioclase shows well-developed Carlsbad and Albite twinning. The rest of the sample consists of hornblende, biotite, hypersthene, ilmenite, apatite, and perthite. Sericite, garnet, chlorite, and zircon can be found as accessory minerals. Hypersthene-hornblende-ilmenite intergrowths are present. Much of the biotite has been altered to either ilmenite, garnet, or chlorite.

2907875C

This sample also represent the transition zone between the two metamorphic facies. Dominant minerals are plagioclase (45%) and hornblende (30%). Other minerals are coarse-grained hypersthene, clinopyroxene, ilmenite, and apatite. Accessory minerals such as biotite and zircon are also present. The sample is well foliated. Two types of intergrowths are seen, hypersthene-hornblende-ilmenite and hypersthene-clinopyroxene intergrowths.

2907885B

This sample was collected in the zone of high grade metamorphism. The sample consists of approximately 45% plagioclase, but much quartz (20%) and hornblende (20%) are also present. Perthite, biotite, and ilmenite can also be found. Accessory minerals are clinopyroxene, chlorite, apatite, sericite, and zircon. The sample is well foliated. Chlorite-ilmenite intergrowth is present.

2907885C

This sample is dominated by plagioclase (35%), quartz (25%), perthite (20%), and hornblende (15%), as was sample 2907885B. Small amounts of biotite and ilmenite are also present. Accessory minerals are clinopyroxene, chlorite, sericite, apatite, sphene, zircon, and epidote. It is well foliated. Chlorite-ilmenite-hornblende intergrowth are present. Many of the minerals show alteration.

*Based on work by Cramer, 1989.

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